Occulter Concept Technology Assessment

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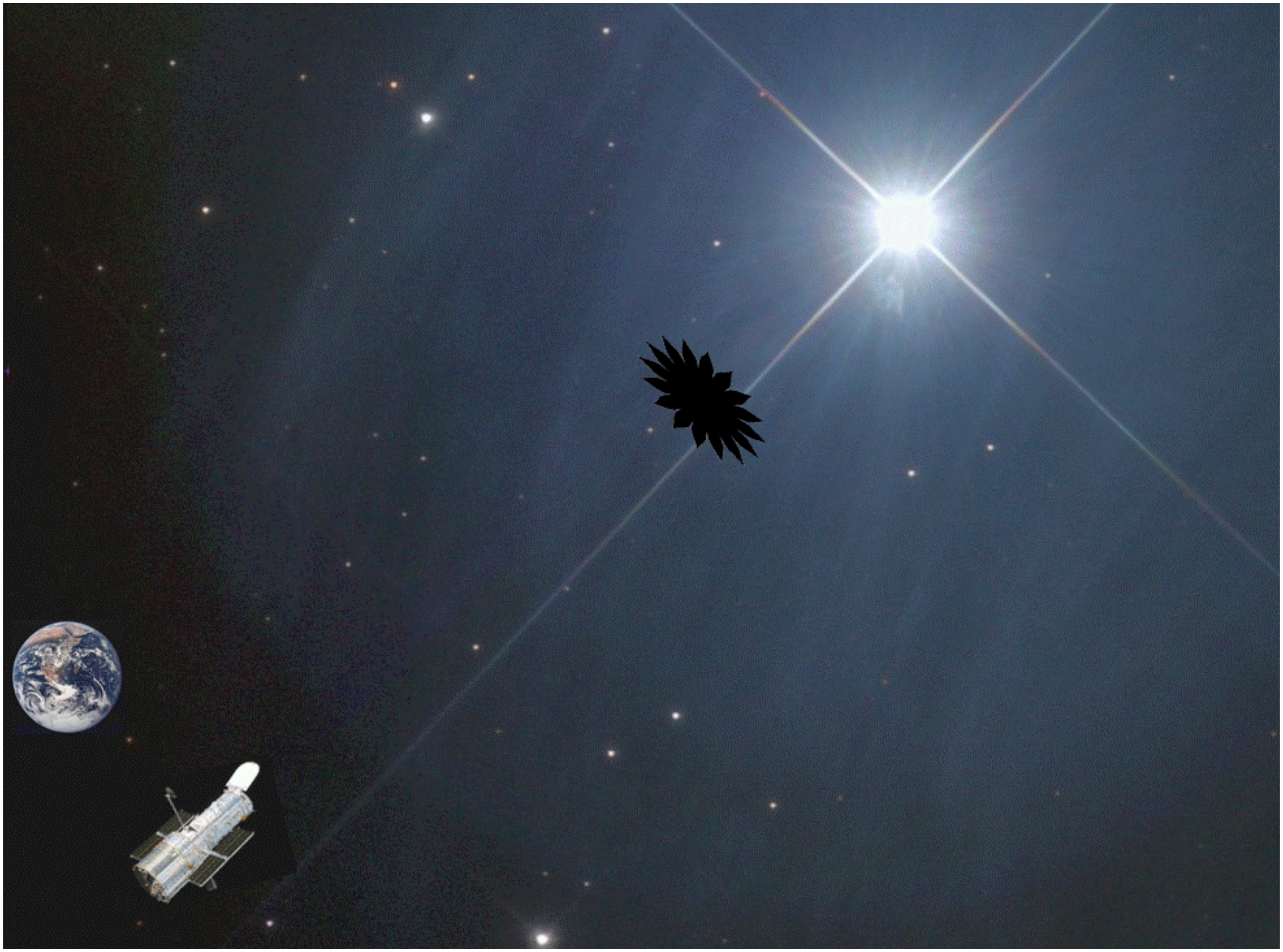
Lockheed Martin Space Systems Company

May 28, 2008



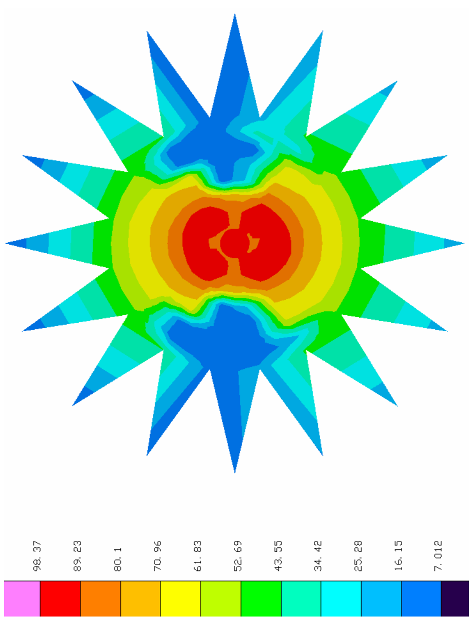
Occulter On-Orbit Thermal Analysis

Based on past experience of working with deployable membranes a thermal analysis of the system led to significant data in defining a technology program. Hence an initial Occulter thermal analysis was completed

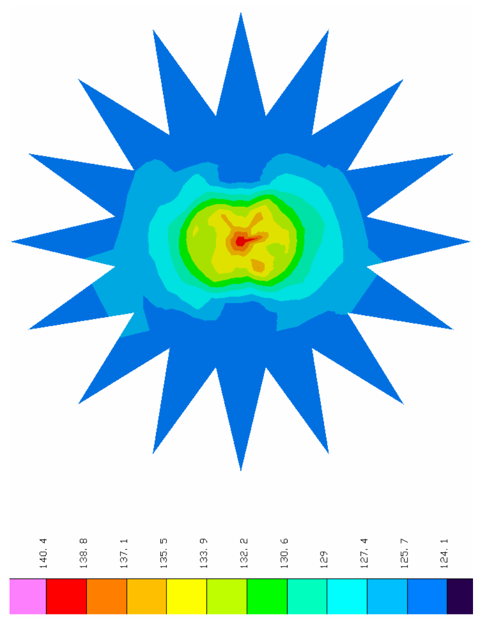
Thermal Model

- Flat, star-shaped Occulter membrane
  - 30 m dia, 16 petals (shape approximation at right)
  - 4 μm Kapton (negligible in-plane conductance)
  - Supporting structure not included
  - α/ε = .93/.80 both sides
- Spacecraft bus
  - 2 m diameter, 20 cm thick disk, temperature 300K
  - 1 m above the center of membrane
  - radiators on the cylindrical surface
  - low emittance on membrane-facing side
  - 1 m x 2 m solar panel on top of bus, normal to the sun, in thermal equilibrium with the radiation environment.
- L2 orbit, sun incidence angle measured from plane of the Occulter. Space sink temperature 7K.

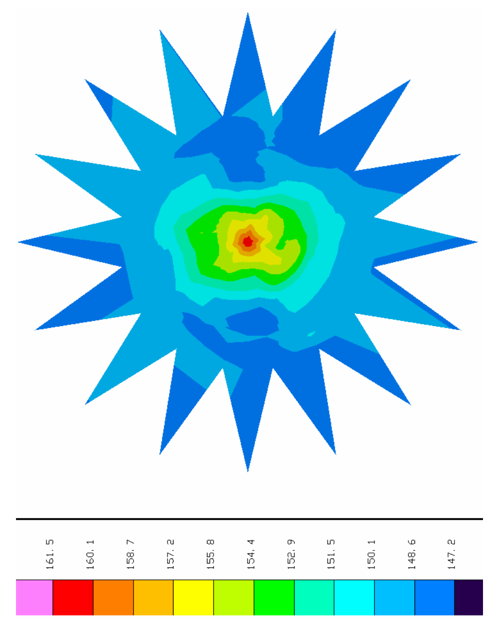
Temperature Distributions as a Function of Solar Incidence



0° solar incidence angle
Temp range 7.01K – 98.4K

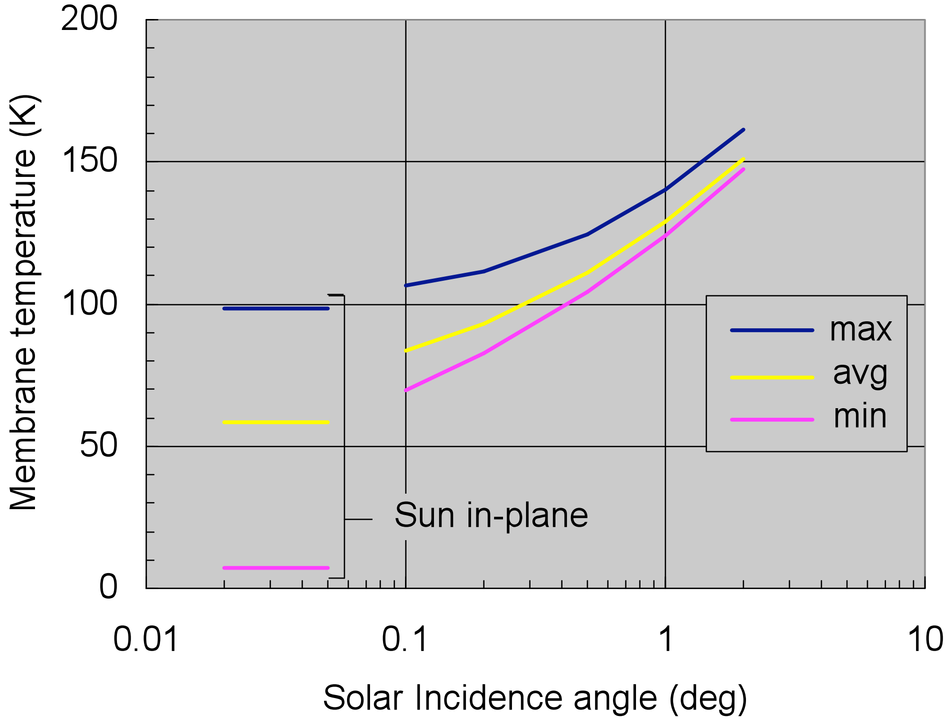


1° solar incidence angle
Temp range 124.1K – 140.4K



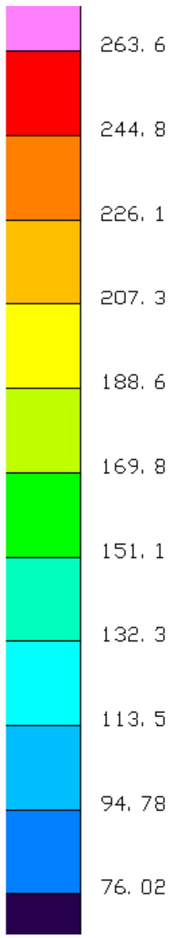
2° solar incidence angle
Temp range 147.2K – 161.5K

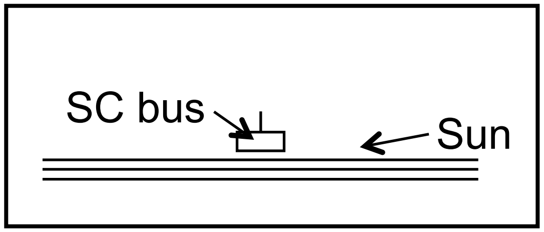
Membrane Temperature
Sensitivity to Solar Incidence Angle



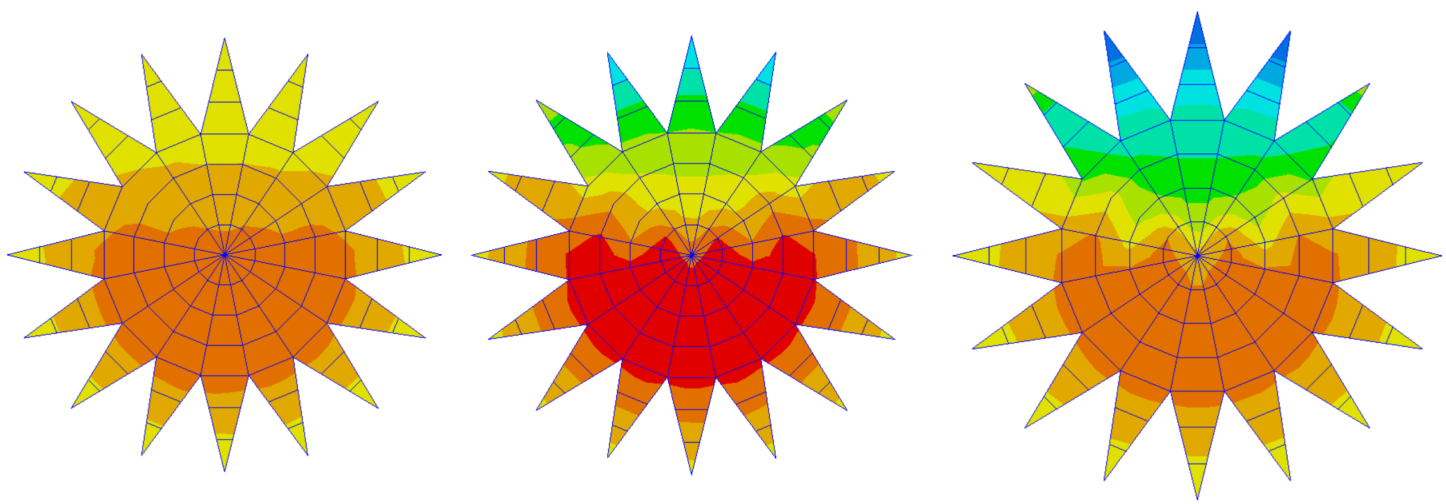
- Results for black coating both sides, $\alpha/e = .93/.80$
- Temperatures 4 – 8°C warmer for single side aluminized 4 μm Kapton (extrapolated optical properties)

Temperature Distributions on 3-Layer Flat Occulter





- 3 flat layers, black coated Kapton, 30 m dia
- SC bus 2 m above top layer
- Layer separation 1 m
- Sun 5° above Occulter



Sun side Center Shade side

Occulter Technology

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Occulter System Maturation

- Material Characterization (including phase changes)
- Coatings and testing
- Material deployment stowage and shelf life
- Manufacturing technique
- Deployment Dynamic /accuracy
- Optical design & modeling methods
- Thermal design & modeling methods
- Mechanical design & modeling methods
- Stray light glint from the Sun

Formation Flying

- Formation flying
- Control algorithms

Pointing Control Subsystem

- Response of the Occulter to spacecraft dynamic forces
- Isolation system between Occulter and its spacecraft ?
- Thruster firings

Micro-Meteroids

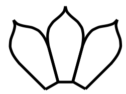
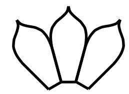
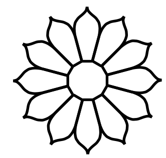
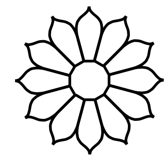
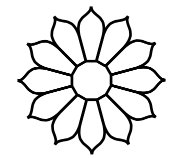
- Micro-meteroids, dynamic response/ stray light

Inflatable

- Alternative Rigidizable Inflatable

- Propulsion system /contamination
- Metrology
- System modeling analysis for alignment budgets (from manufacturing to zero G on-orbit)

Occulter System Maturation

 **TRL 3 Proof of concept**	 **TRL 4 Component level**	 **TRL 5 Component level**	 **TRL 6 Subscale protoflight occulter**	 **TRL 7 Subscale protoflight occulter**	 **TRL 8 Subscale protoflight occulter**
• ~1m size • Deployment • Shape accuracy • Model development **Coupon Testings** Material properties at temperature • Mechanical • Thermophysical • Optics • Environmental stability	• Functional performance in air • 2 – 3m size, 3 petals, data on central petal • Deployment • Loads/stresses • Shape accuracy and stability • Gravity effects • Model validation • Scaling	• Functional performance in thermal vacuum • 2 – 3m size, 3 petals, data on central petal • LN2, IR • Loads/stresses • Shape accuracy and stability • Model validation • Scaling • Optics	• Functional performance in air • 8-30m size, full configuration for microsat • Deployment • Loads/stresses • Shape accuracy and stability • Gravity effects • Model validation • Scaling • Optics	• Qual/acceptance test flight article • 8-30m size, full configuration for microsat • Deployment • Loads/stresses • Temperatures • Shape accuracy and stability • Model validation • Acoustic env • Thermal vac • Optics	• On orbit demo • 8-30m size, full configuration on microsat • Deployment • Loads/stresses • Temperatures • Shape accuracy • Model validation • Formation flying • Attitude control

ST-9 Large Space Telescope

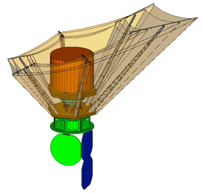
Sunshade Deployment/Packaging Technology Development

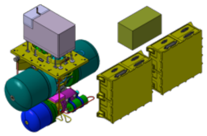
Jason Tolomeo
Lockheed Martin Space Systems Company
Advanced Technology Center

August 17, 2006

ST-9 Large Space Telescope

Design and Nomenclature


LM Sunshade


NG Cryocooler

The sunshield design consists of :

5 layer membrane layers forming a faceted cone.

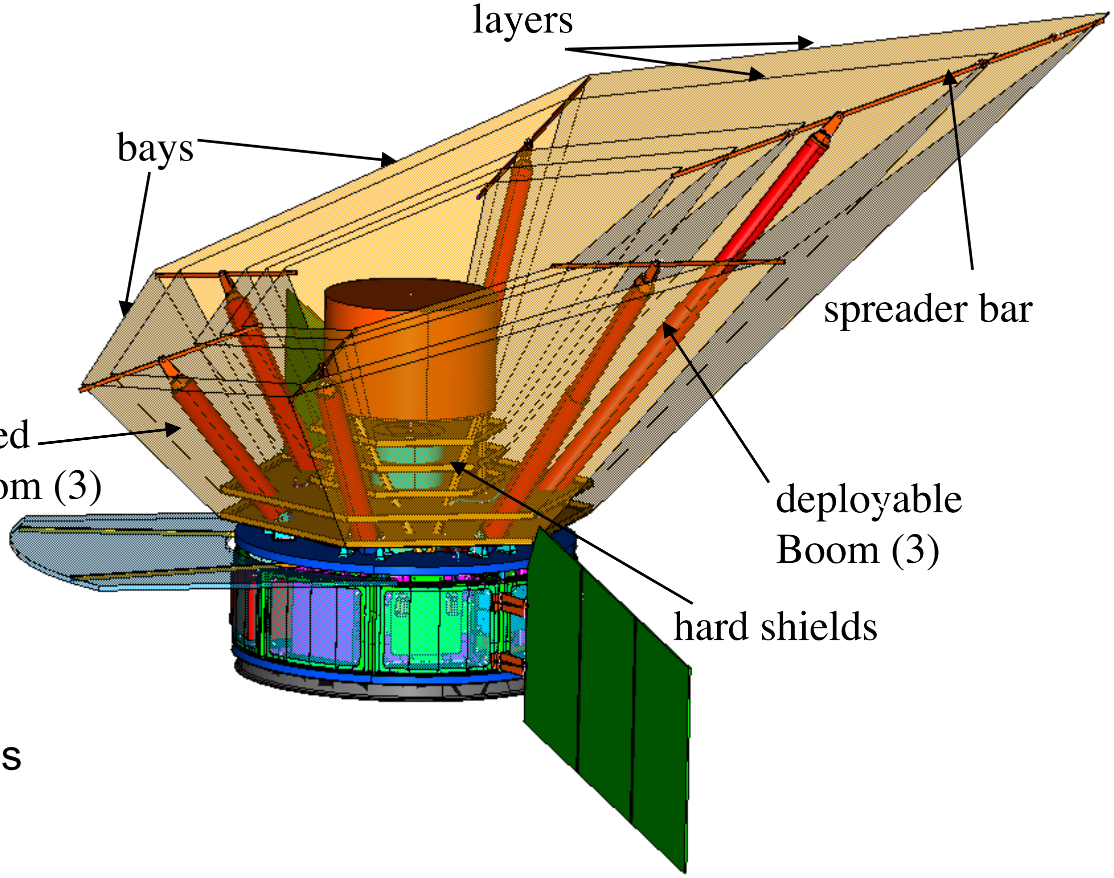
Shape set to exclude sun and earth radiation

3 degree interior angle Between layers.

Each interior layer made of ~1mil double aluminized Kapton

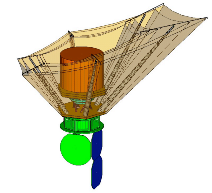
Deployment using 3 high authority telescoping booms and 3 fixed booms (Delta)

Approximate dimensions 1.5m x 3m

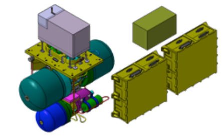


ST-9 Large Space Telescope

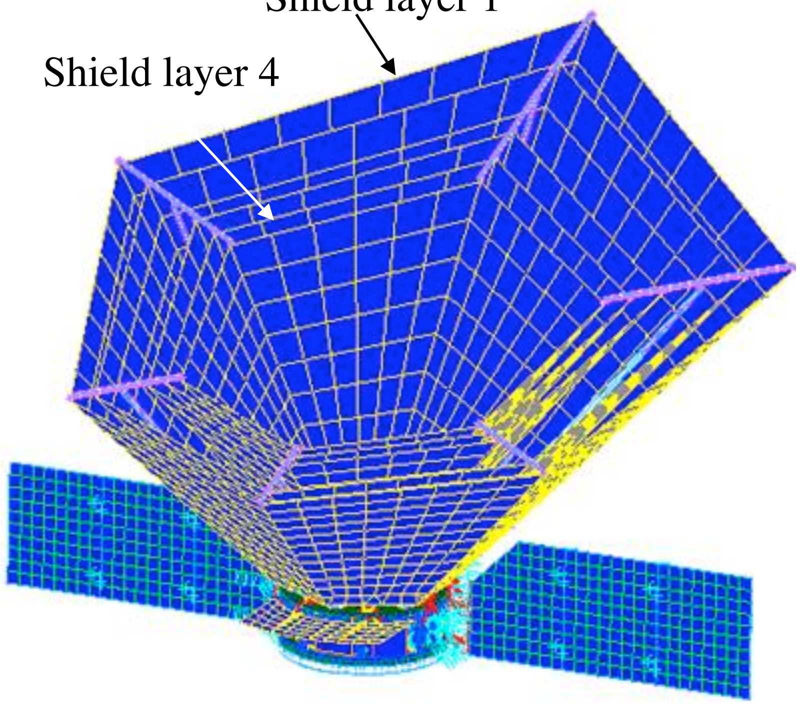
Test Configuration



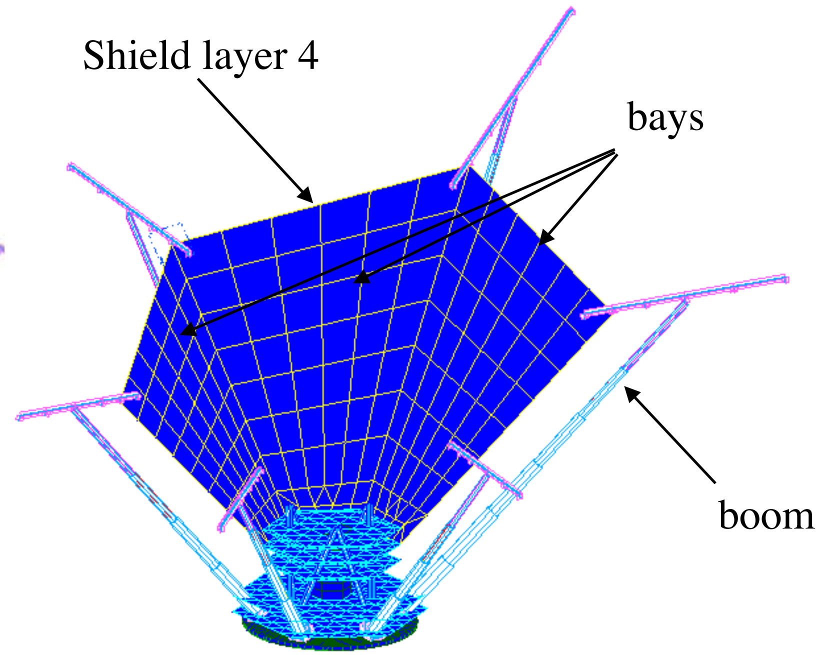
LM Sunshade



NG Cryocooler



Flight Configuration

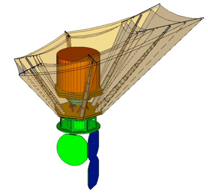


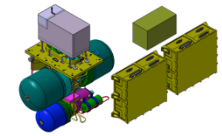
Testbed Configuration

- Test configuration is three bays, 1 layer, four booms (part of shield number 4)
  - Full scale
  - Interior bay has appropriate boundary conditions. Surface measurements taken on inner bay, load cell data taken at vertices.

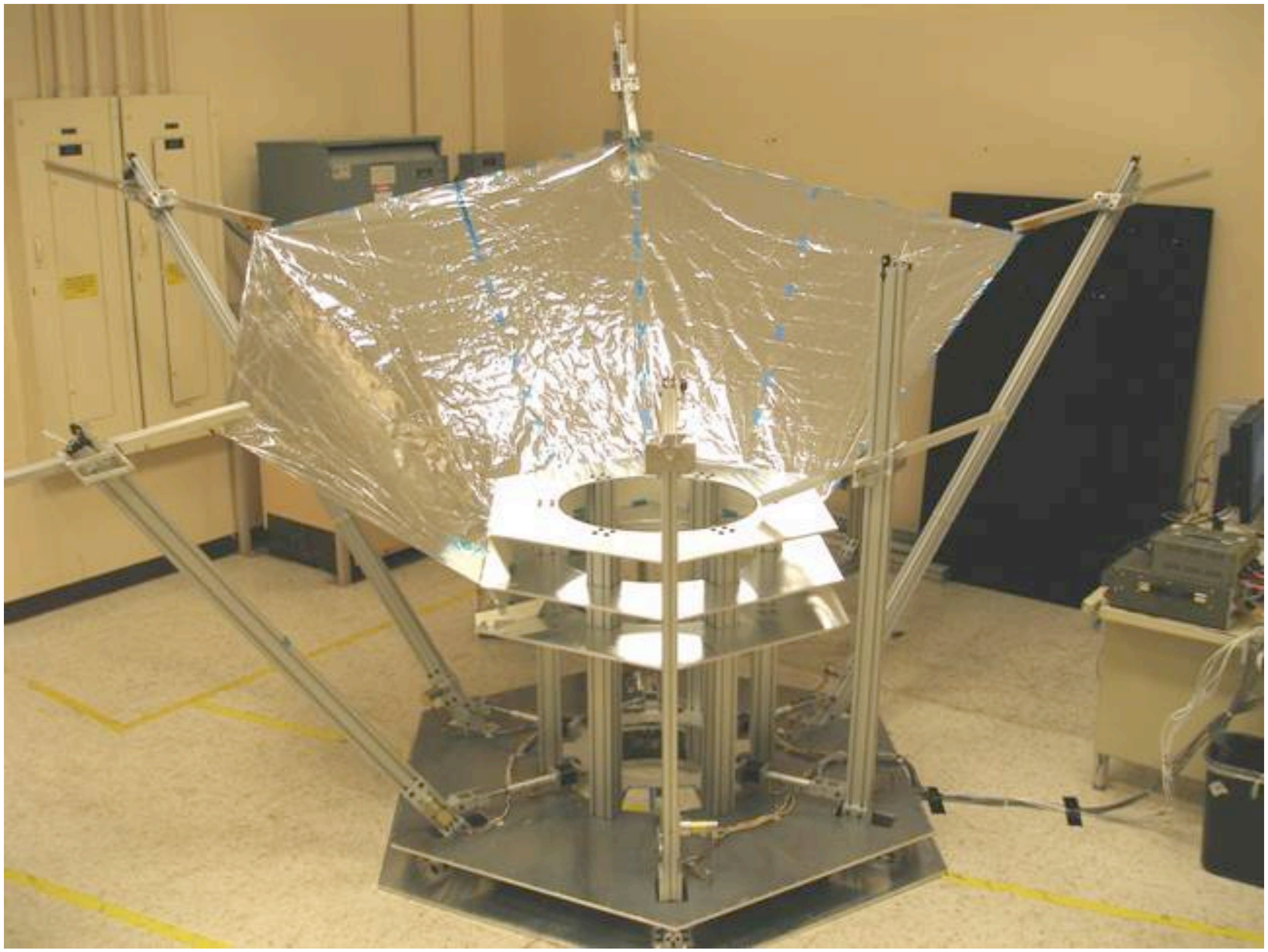
ST-9 Large Space Telescope

Full Scale Deployment Testbed





NG Cryocooler

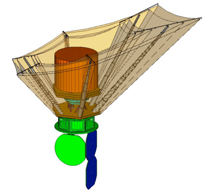


3m

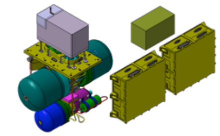
Designed for growth path to 3 layers and 6 booms for Formulation Phase testing

ST-9 Large Space Telescope

System Deployment



LM Sunshade



NG Cryocooler

Video:
System_deployment_animate.pps

Formation Flying

Formation Flying Occulter Requirements

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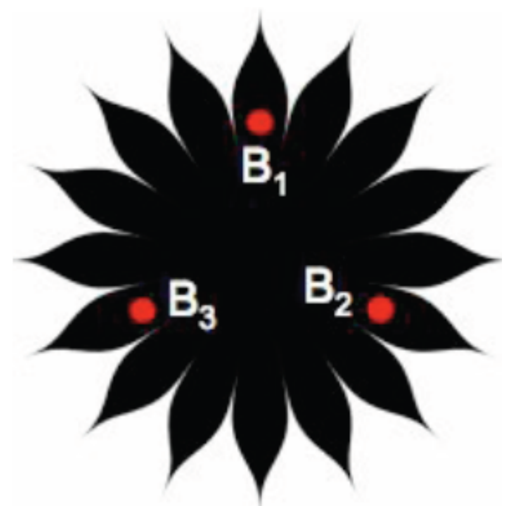
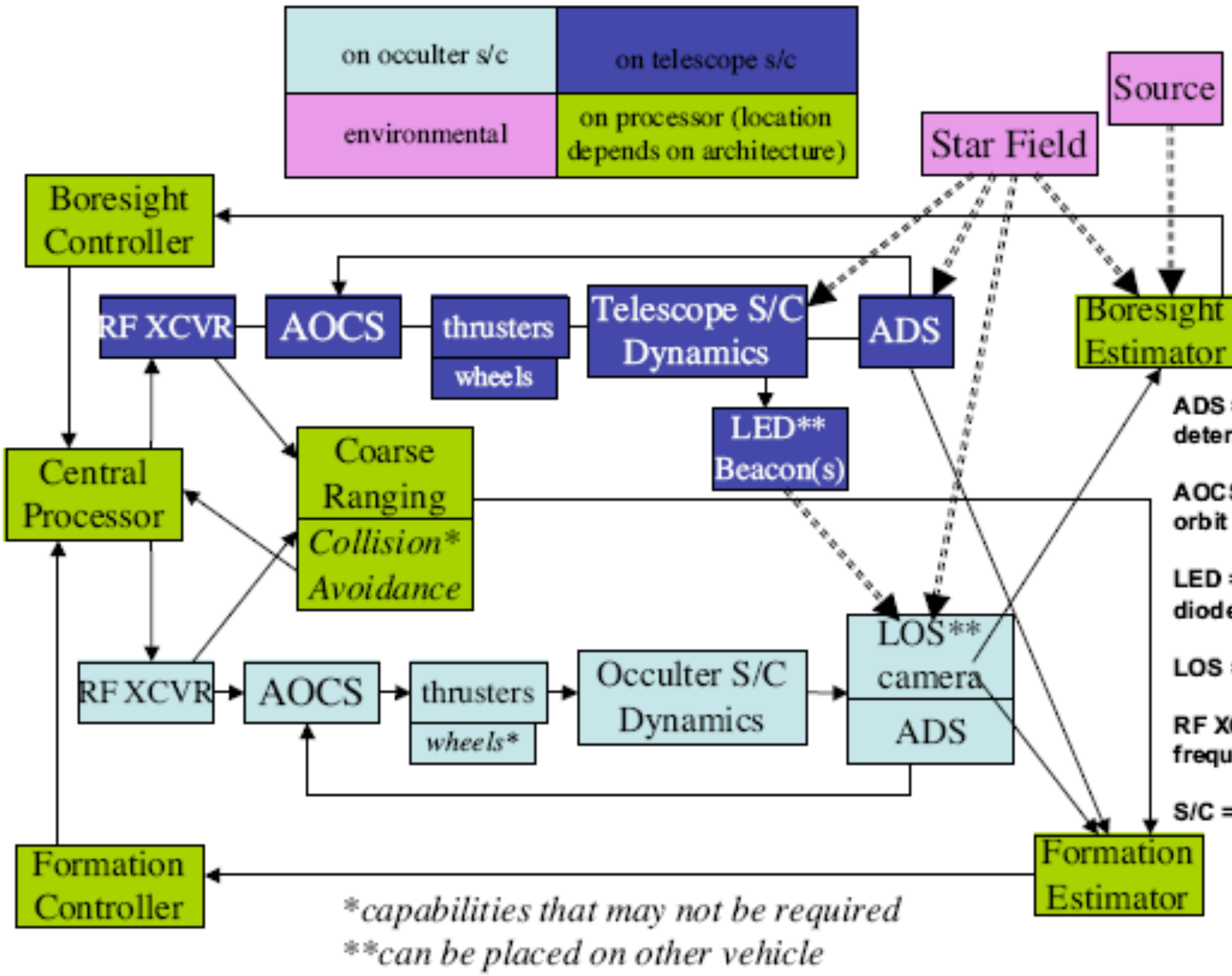
- Rigid Body Motion
  - 1 meter motion in the plane
  - ±3 arc seconds tilt
  - Roll (TBD)
- Occulter Acquisition and Pointing
  - 3 beacon concept defined in R. Lyon (lead author) paper
  - Testbed plan in development



Beacon concept

Formation Flying Block Diagram



ADS = attitude determination system

AOCS = attitude and orbit control system

LED = light-emitting diode

LOS = line-of-sight

RF XCVR = radio frequency transceiver

S/C = spacecraft

Jesse Leitner Block diagram for Formation Flying and GNC Subsystem

Pointing Control Subsystem

Pointing Control Subsystem (PCS) Technology Development

- The PCS Algorithms that may require development will have to consider the flexible body dynamics of the large Occulter plus the much smaller deployable Solar Array and High Gain Antenna. Included in the control of the system is thruster firings, reaction wheel forces, micro-meteroid impacts, thermal deformations which cause the center of mass and center of pressure to vary after slewing.

Micro-Meteroids

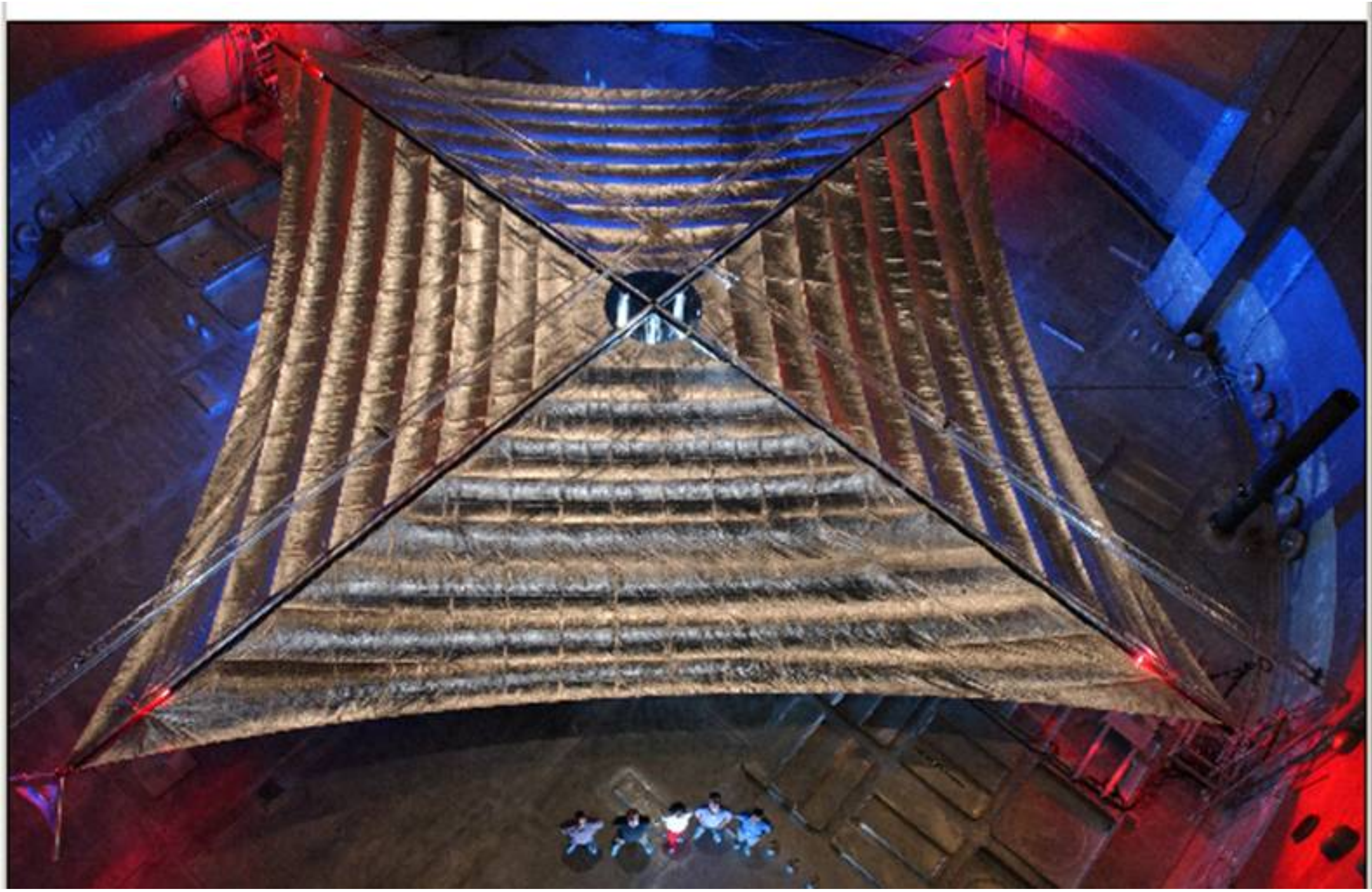
Micro-Meteroids Impacts

- Determine Micro-Meteroids effects on the Occulter relative to:
  - Stray light
  - Dynamics
- Quantify Environment
  - TBD impacts/ yr with mass >10^{-7} G (velocity 20-50 Km/s)
- Complete Micro-Meteroids development tests on multilayer Occulter material

Rigidizable Inflatable

L'GARDE, INC.

20m deployed Solar Sail @ Plum Brook



Preliminary ROM Mass Estimate

- Rough order-of-magnitude mass properties estimate based on conceptual design in the absence of more precise configuration information

Component	Mass [kg]
R/I (Solar Sail Boom Laminate)	62.8
MLI	1.3
Ties	0.0684
N2 Pressurant	0.004
Tank	0.80
Restraint System	2
Other	4.0
Sub-Total	71.0
10% Margin	7.1
Total	78.1

Backup Chart

External Coronagraphs Requirement

External Coronagraphs										
Mission type/size	Raw Contrast	Augmented contrast	IWA (mas)	Telescope Pointing Stability during exposure	Occulter Position to the star	Telescope Thermal stability	Optics Quality & Fabrication	Edge Tolerances	System Integration & Test	Driving science
4-m telescope 50m occulter tip/tip 72000 km separation	1.00E-10 at smallest IWA Full 100% bandwidth 300-1100nm	1.00E-11	60 mas	< 10 mas	0.5 m		On axis, diffraction limited, HST stability	< 1mm	By analysis only	Earths to Jupiters, R = 40
4-m Hybrid 36m occulter tip-tip occulter 50000 km separation	1.00E-10 at smallest IWA Full 100% bandwidth 300-1100nm	1.00E-11	60 mas	< 1 mas	0.5 m		On axis diffraction limited, HST stability	< 1 cm	By analysis only	Earths to Jupiters, R = 40

The raw contrast is the ratio between PSF surface brightness at the location of the planet and the PSF surface brightness at the PSF core. The augmented contrast is defined here as the contrast after PSF subtraction / calibration schemes have been applied.

Summary/Conclusion

Summary Coronagraph/ Occulter

- Summary of technologies provided for Coronagraphs Occulters
- More detailed technology plans with cost to be developed
- Coronagraph technology development is further advanced than Occulters particularly in the key area of deformable mirrors
- A hybrid of Coronagraph/Occulter system utilizes the advances made in Coronagraph technology